

STUDIES ON THE SYSTEMATICS AND DISTRIBUTION OF THE SCORPION *VAEJOVIS BILINEATUS* POCOCK (VAEJOVIDAE)

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ABSTRACT. A revised diagnosis is given for the scorpion *Vaejovis bilineatus* Pocock, a member of the *eusthenura* group, based on newer characters of taxonomic importance. New distributional records presented herein expand the known range of the species to cover much of northeastern Mexico, specifically the states of Coahuila, Nuevo León, Tamaulipas, Aguascalientes, Guanajuato, and San Luis Potosí. The results of an analysis of character variation involving coloration, pectinal tooth counts, pedipalp chela finger dentition, trichobothrial patterns, morphometrics, and setal counts of the pedipalps and metasoma are also provided.

The scorpion *Vaejovis bilineatus* Pocock was described in 1898 on the basis of a single female specimen that supposedly originated from San Diego, Texas (Pocock 1898). Kraepelin (1899) regarded *V. bilineatus* as a variant of *Vaejovis spinigerus* (Wood), but this view was overturned by Hoffmann (1931), who recognized *V. bilineatus* once again as a valid species. Hoffmann somewhat tentatively referred his 20 specimens from Tepezala, Aguascalientes, Mexico to this species because they closely matched the original description. The type specimen of *V. bilineatus* was subsequently studied and redescribed by Williams (1970), and that author accepted Hoffmann's specimens as *V. bilineatus*, based on comparison of the holotype to Hoffmann's detailed description. Our findings, based on reexamination of some of Hoffmann's specimens, are in full agreement with those of Williams.

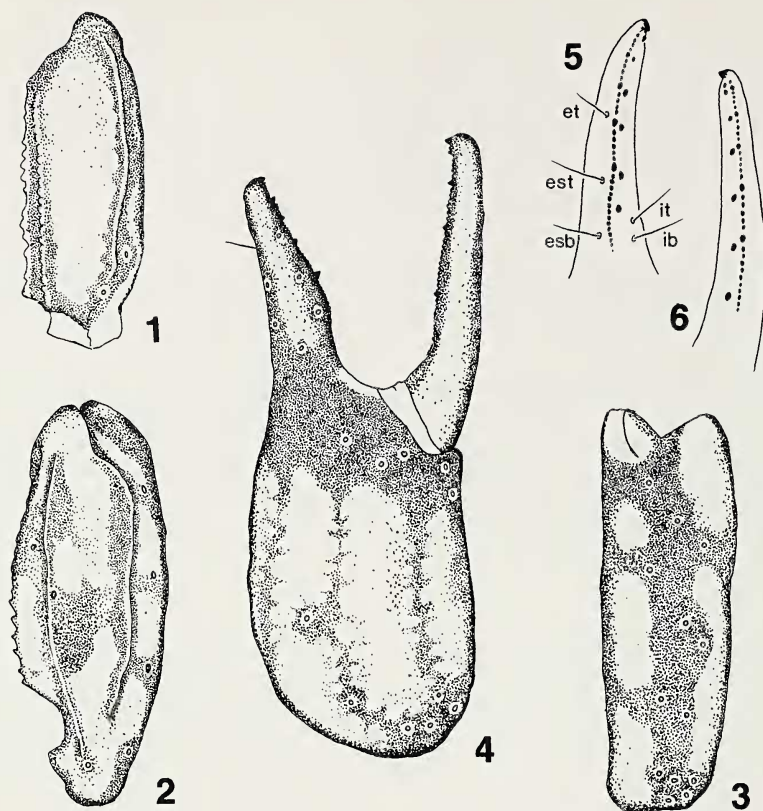
The distribution of *V. bilineatus* has remained poorly understood. Although the fauna of southern Texas is fairly well known, *Vaejovis bilineatus* has not been collected in the state subsequent to the original description. It is likely, therefore, that the holotype was mislabeled, and its locality data are erroneous. Díaz Nájera (1975) listed a single new record for Coronea, Guanajuato and Sissom & Francke (1983), in a life history study of the species, reported a new record for Villa Hidalgo, San Luis Potosí. Díaz Nájera's spec-

imens were not examined and his record, which lies far to the south, will probably require subsequent confirmation. Consequently, after nearly 100 years there are only two or three published localities for *V. bilineatus* that can be considered accurate.

Since these earlier studies, a number of new specimens have accumulated in various museum collections, particularly the American Museum of Natural History (AMNH) in New York, the Texas Memorial Museum (TMM) in Austin, and Museum of Zoology at Louisiana State University. The latter specimens are now deposited in the Florida State Collection of Arthropods (FSCA) in Gainesville. These new specimens allowed us to update the diagnosis for the species based on taxonomic characters recently found important, describe in good detail the geographical distribution of the species, and analyze variation in color, morphometrics, and meristics. Morphometric characters are derived from measurements of 12 adult males and 12 females; for other characters studied, almost all adult and late instar juvenile specimens available were utilized. All measurements were taken using an ocular micrometer calibrated at 20×.

Vaejovis bilineatus Pocock (Figs. 1-21)

Vaejovis bilineatus Pocock 1898:395; *nec* Gertsch 1939:18 (misidentification, = *V. waueri* Gertsch & Soleglad 1972); Gertsch & Soleglad 1972:605; Stahnke 1974:135; Díaz Nájera 1975:6, 8, 22;



Figures 1–6.—Morphology of *Vaejovis bilineatus*, male from Villa Hidalgo, San Luis Potosí. 1, Pedipalp femur, dorsal aspect; 2, Pedipalp patella, dorsal aspect; 3, Pedipalp patella, external aspect; 4, Pedipalp chela, external (lateral) aspect; 5, Pedipalp chela fixed finger, showing dentition and trichobothrial pattern; 6, Pedipalp chela movable finger, showing dentition. Trichobothrial designations for Fig. 5 are as follows (after Vachon 1974): *esb* = external subbasal; *est* = external subterminal; *et* = external terminal; *ib* = internal basal; *it* = internal terminal.

Sissom & Francke 1983:69–75; Francke & Sissom 1984:17, tables 6, 7.

Vaejovis spinigerus var. *bilineata* Kraepelin 1899: 187.

Vejovis bilineatus Hoffmann 1931:347 (key), 362–364, fig. 26; Williams 1970:238–241, figs. 1, 2.

Description.—Adults 22–32 mm in length. Base color yellow brown; carapace with dark underlying pattern; mesosomal dorsum usually with one pair of moderately dark, longitudinal submedian stripes (in some populations there are dark lateral blotches on each tergite as well); metasoma with variable mottling on dorsal and lateral faces and with ventral submedian and ventrolateral carinae underlined in dark pigment; metasomal segment V and sometimes IV slightly darker than preceding segments, particularly on underside. Carapace with anterior margin more or less

straight, but with small median notch. Sternite VII with carinae obsolete. Pectinal tooth counts 15–19 in males and 14–16 in females. **Metasoma:** Segments I–III wider than long, V 2.00–2.38 times longer than wide in males, 1.78–2.18 times longer than wide in females; ventral submedian carinae on I–IV obsolete, sometimes weak, crenulate on IV; ventrolaterals on I–IV moderate, smooth to crenulate. **Pedipalps:** Femur tetracarinate with carinae of dorsal surface moderate, crenulate (Fig. 1); patella (Figs. 2, 3) with dorsointernal and dorsoexternal carinae weak, smooth to granular in males and faint, smooth in females; inner face moderately convex, with inner keel granular in males, smooth to granular in females. Chela (Fig. 4) with all carinae essentially obsolete; chela fixed finger (Fig. 5) with primary denticle row divided into five sub-rows; mov-

able finger (Fig. 6) with primary row divided into six sub-rows (including the apical sub-row containing a single small denticle); male palm slightly swollen, female palm slender; cutting margins of male chela fingers moderately scalloped, female fingers with cutting margins straight. Pedipalp chela length/width ratio, 2.81–3.55 in males, 3.37–4.00 in females; pedipalp femur length/carapace length ratio, 0.67–0.73 in both sexes; pedipalp patella length/width ratio, 2.22–2.64 in both sexes; chela fixed finger length/carapace length ratio, 0.48–0.55 in both sexes; chela movable finger length/chela width ratio, 1.58–2.0 in males, 2.03–2.38 in females; chela movable finger length/metasoma V length ratio, 0.54–0.61 in males, 0.62–0.68 in females. Trichobothria *ib* and *it* situated near the sixth (basalmost) inner accessory denticle of fixed finger denticle row, usually with *it* at the level of or slightly basal to the denticle.

Specimens examined (all from Mexico).—*Agascalientes*: 2 mi W Asientos (7300 ft.), 9 June 1956 (B. Banta), 2♂, 1♀ with 19 1st instar young (AMNH); Tepezala, no date (C. C. Hoffmann), 4♂4♀ (AMNH—C. C. Hoffmann Collection). *Coahuila*: 5.4 mi W Bunuelos in Valle de Guerra, 15 July 1977 (E. A. Liner, Chaney), 2♀ (FSCA). *Nuevo León*: 4.5 mi N La Ascension, 19 July 1975 (E. A. Liner), 2♀ + 9 1st instar young (FSCA); 6.9 mi W El Carmen, 15 July 1976 (E. A. Liner, et al.), 1♀ (FSCA); 2.7 mi N, 2.4 mi SE La Ascension on La Caballada Road, 19 July 1975 (E. A. Liner, et al.), 2♂3♀ (FSCA); 7.7 mi N La Ascension, 19 July 1975 (E. A. Liner), 2♂1♀ (FSCA); 3 km S San Roberto (under cactus), 13 Aug 1972 (N. V. Horner), 1♀ (WDS). *San Luis Potosí*: 22 mi S Huizache, 20 Sept 1979 (J. C. & J. E. Cokendolpher), 1♂ (WDS); KM 20 on Hwy 70, March 1972 (collector unknown), 2♂1♀1juv. (AMNH); 40 mi W Valles, March 1972 (collector unknown), 1♀2juv. (AMNH); Hwy 70, 70 mi W Valles, 19 February 1970 (J. A. L. Cooke, R. W. Mitchell), 1♂2♀1juv. (AMNH), 1♂1♀ (WDS); near Ciudad del Maiz, 19 Aug 1947 (C. & M. Goodnight), 1♀ (AMNH); km 50 on Hwy 57, 18 Mar 1972 (J. M. Rowland), 1♂ (TMM); San Luis Potosi (in or near city?), no date (H. F. Wickham), 1♂ (USNM). *Tamaulipas*: km 14 on Hwy 101, 22 Feb 1973 (W. Graham, T. R. Mollhagen, C. McConnell), 3♂8♀2juv. in three vials (AMNH); km 53 on Hwy 101, 23 Feb 1973 (T. R. Mollhagen), 1 subadult♂1♀ (AMNH); km 92 on Hwy 101, 22 Feb 1973 (T. R. Mollhagen) 1♂8♀ (AMNH); km 15 on Hwy 19, 18 Mar 1972 (J. A. L. Cooke), 1♀ (AMNH); 4 mi N Juamave, 20 Sept 1979 (J. C. & J. E. Cokendolpher), 1♀ (WDS); Ciud-

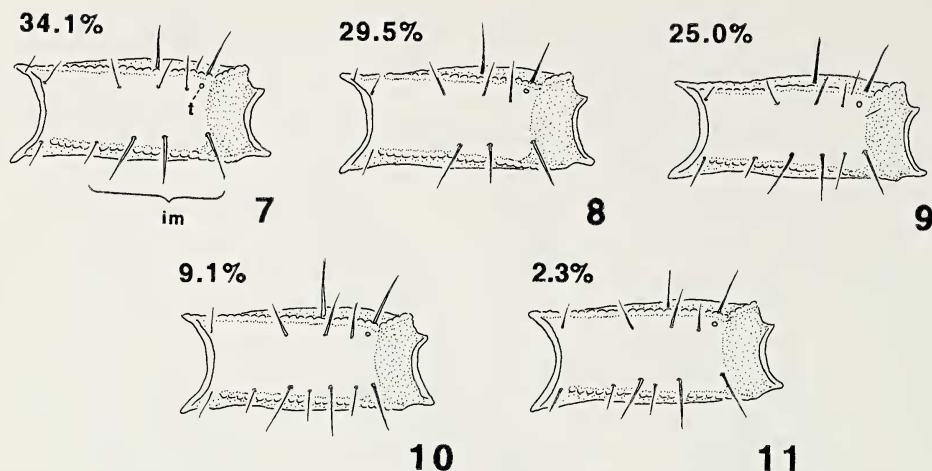
ad Victoria, June 1977 (F. D. White), 1♀ (WDS); 1 km NW La Presita, 20 Sept 1979 (J. C. & J. E. Cokendolpher), 2♀ (WDS); Palmillas, "12–3–64" (T. Raines), 2♀ (AMNH). *State uncertain*: Gonzalez (= Villa González Ortega, Zacatecas?), no date (H. F. Wickham), 2♀ (USNM).

CHARACTER ANALYSIS

Color pattern.—There was considerable variation observed in color pattern, so much so that the name "*bilineatus*" now seems inappropriate. Specimens in some parts of the range, particularly in Tamaulipas and eastern San Luis Potosí, bore not only the distinctive submedian stripes, but also had dark blotches near the lateral edges of the tergites. This gave the scorpions the appearance of having four dorsal stripes rather than two. The variation in color pattern suggested the possible presence of two species; however, the search for additional characters that could consistently distinguish the two color forms was not productive. Further, in the southern part of the range (southwestern San Luis Potosí) specimens were intermediate in color pattern, with diffuse lateral blotches that were essentially continuous with the median stripes. One interesting feature in specimens from eastern San Luis Potosí (those also bearing four dorsal stripes) was a general tendency for the males to have crenulated ventrolateral metasomal carinae on segments I–IV and crenulated ventral submedian carinae on segment IV. However, typical two-striped males in other parts of the range occasionally had weak crenulations on the ventrolateral carinae as well. Consequently, it seems best at this time to regard the color variation as intraspecific in nature.

Pectinal tooth counts.—Pectinal tooth counts varied in the specimens examined as follows (damaged combs were not counted): in males, there were 3 combs with 15 teeth, 21 combs with 16 teeth, 22 combs with 17 teeth, 1 comb with 18 teeth, and 2 combs with 19 teeth; in females, there were 9 combs with 14 teeth, 41 combs with 15 teeth, and 16 combs with 16 teeth. There was no discernible geographical pattern in pectinal tooth count variation.

Pedipalpal macrosetal counts.—Haradon (1983, 1984a, 1984b, 1985), in his revisionary work on the genus *Paruroctonus* Werner, found the numbers and distribution of pedipalpal macrochaetes to provide good specific



Figures 7–11.—Variation in setation of the internal (anterior) face of the pedipalp femur in *Vaejovis bilineatus*. Percentages represent the proportion of specimens ($n = 44$) that bore the particular setal pattern. Designations are as follows: t = trichobothrium; im = inframedial setae.

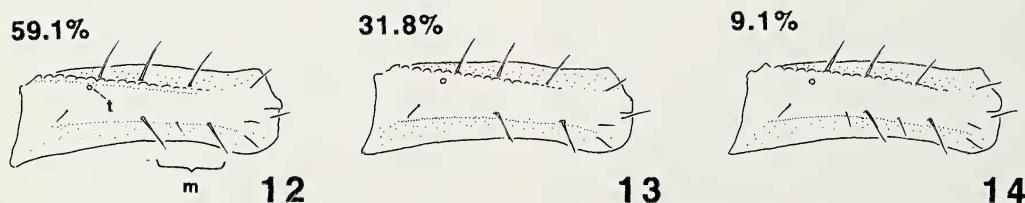
characters. It is worthwhile, as Haradon suggested, to investigate these characters in other vaejovids, so we conducted a thorough analysis on our specimens of *V. bilineatus*. Our findings indicated that the setal characters exhibited high intraspecific variation that was not geographically based. The patterns of the femoral and patellar setae are described and illustrated below; the frequency of occurrence of each pattern is provided with its illustration.

For the inframedial setae of the inner face of the pedipalp femur, five relatively distinct setal patterns were identified (Figs. 7–11), three of which were prevalent. In each pattern, there were three larger setae evenly spaced from the base of the femur; in addition, there were variable numbers of smaller setae (none, one, two, or three). These smaller setae were usually directly in the row, but in some cases were positioned closer to the ventrointernal carina. There were also instances where the

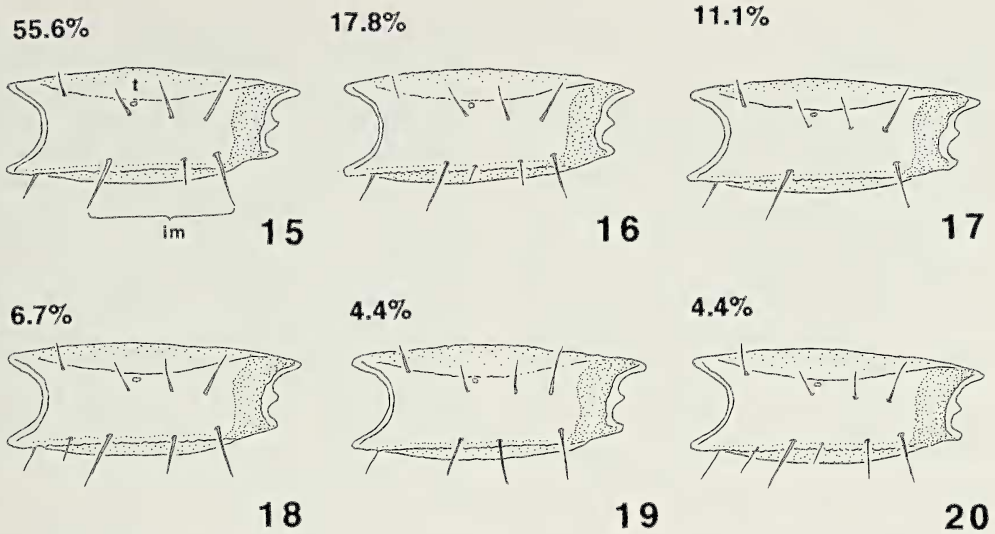
setae were so small that, in our judgment and according to Haradon's definition, they should not have been classified as macrosetae. In such cases, the setae were not counted.

Another set of diagnostic setae was the medial series of the external face of the femur (Figs. 12–14). As shown in the figures, three distinct patterns were observed. In each, there were two major setae. Usually, in between the two major setae was another smaller seta that was quite variable in size. In many cases this seta was missing, as evidenced by a tiny socket. Based on the size of the socket, the specimen was more or less arbitrarily assigned to either the first (Fig. 12) or second setal pattern (Fig. 13). There were also cases in which no socket could be detected at all (Fig. 13). Finally, in a few specimens, a small seta occurred on the proximal side of the two majors (Fig. 14).

Six distinct patterns occurred for the inframedial setae of the internal face of the patella



Figures 12–14.—Variation in setation of the external (posterior) face of the pedipalp femur in *Vaejovis bilineatus*. Percentages represent the proportion of specimens ($n = 44$) that bore the particular setal pattern. Designations are as follows: t = trichobothrium; m = medial setae.



Figures 15–20.—Variation in setation of the internal (anterior) face of the pedipalp patella in *Vaejovis bilineatus*. Percentages represent the proportion of specimens ($n = 45$) that bore the particular setal pattern. Designations are as follows: *t* = trichobothrium; *im* = inframedial setae.

(Figs. 15–20). There were always two large, thick setae around which were interspersed variable numbers of smaller setae. The size of these smaller setae varied considerably from specimen to specimen—in some cases, they were quite short and thin and in others, relatively long and thick. In the latter case, they were almost as long as the two major setae, but were never as thick.

Tarsal setae.—Setae of the retrolateral aspect of tarsomere II (= telotarsus II) of the leg (leg III was utilized here) were consistent in number and position throughout the range of the species. There were two retrosuperior setae and two retromedials (see Haradon 1984 for explanation of terminology).

Metasomal setation.—Metasomal setation was highly variable, owing to the presence of numerous accessory setae of varying sizes on and between the keels (especially on the ventral surface). In many cases the setae were missing, leaving only the socket. Consequently, interpreting the pattern of pairing was sometimes subjective. The larger setae actually positioned on the carinae of 48 specimens were counted; segments in which the counts were questionable were not tallied in the results.

Setation of the dorsolateral carinae of segments I–IV: Only setae of the carinae of the left side were counted, and a modal count of

1:2:2:3 was obtained. Segment I had either one (70.8% of the specimens) or two (29.2%) setae; segment II had either one (4.3%), two (78.3%), three (10.9%), or four (6.5%) setae; segment III had either two (68.1%), three (23.4%), four (6.4%), or five (2.1%) setae; and segment IV had either two (21.3%), three (55.3%), four (14.9%), five (6.4%), or six (2.1%) setae.

Setation of the ventral submedian carinae of segments I–IV: Because the setae of the two keels were easily inspected simultaneously, they were counted on both sides. There was a modal setal count of 3/3:4/4:4/4:5/5 with variable numbers of accessory setae located between the carinae on each segment. Segment I was very uniform (91.3% of the specimens exhibited the modal count, with only a few specimens bearing four setae on one side or both); however, there was great variability on segments II–IV. For segment II, 25% of the specimens possessed a 3/3 count; 10.4% a 3/4 count; 37.5% a 4/4 count; 16.7% a 4/5 count; and 10.4% a 5/5 count. For segment III, 4.3% exhibited a 2/4 count; 8.7% a 3/3 count; 17.4% a 3/4 count; 30.4% a 4/4 count; 8.7% a 4/5 count; 6.5% a 4/6 count; 21.7% a 5/5 count; and 2.2% a 6/6 count. For segment IV, 5.0% possessed a 3/4 count; 15.0% a 4/4 count; 20.0% a 4/5 count; 2.5% a 4/6 count;

47.5% a 5/5 count; 5.0% a 5/6 count; and 5.0% a 6/6 count.

Setation of the dorsolateral and ventrolateral carinae of metasomal segment V: (left side only counted in both cases) The dorsolateral carina bore 7–12 setae, with nine (36.6%) and 10 (29.3%) being the most common numbers; lower percentages of specimens had eight (12.2%), 11 (9.8%), seven (7.2%), and 12 (4.9%). The ventrolateral carina bore 7–13 setae, again with 9 and 10 representing the most common observations (37.5 and 25.0%, respectively); all other setal counts occurred at frequencies of 10% or less.

Trichobothrial pattern.—Trichobothrial numbers tend not to vary in species of *Vaejovis* Koch, except for certain species in the *nitidulus* group (Sissom & Francke 1985), in which there is a single accessory trichobothrium on the external face of the pedipalp patella. Trichobothrial positions also tend to be relatively stable, although certain trichobothria may occur in locations that provide diagnostic characters for species groups. One important trichobothrial pair, *ib* and *it* on the chela fixed finger, varies in position from group to group. *Vaejovis bilineatus* seems most closely related to *V. waueri* Gerstch & Soleglad, *V. punctatus* Karsch, and *V. spinigerus* (Wood); the latter has been placed by Williams (1980) in the *eusthenura* group. In all members of the *eusthenura* group, *ib* and *it* are displaced distally from the base of the fixed finger to near the level of the sixth inner accessory denticle. As observed in *V. bilineatus*, slight variation does occur in the relative positions of these trichobothria. Trichobothrium *it* may occur at the level of the sixth inner accessory denticle or just proximal to it (Fig. 5); because *ib* is always a set distance from *it*, its position will vary accordingly.

Pedipalp chela finger dentition.—In all vaejovids except *Serradigitus* Stahnke, pedipalp chela finger dentition has been accepted as a very stable character. Much of the variation in the number of denticle sub-rows and inner accessory denticles appears to be due either to developmental anomalies or to injuries that were improperly repaired during molting. Only in *Serradigitus* spp. is significant 'normal' intraspecific variation in these characters observed.

Variation in chela finger dentition has never been quantified. Therefore, during the current

study the right chela fingers of 46 specimens of *V. bilineatus* were analyzed. In 43 specimens (93.5%), the primary denticle row of the fixed finger was divided into five sub-rows by four enlarged primary row denticles (Fig. 5); in two specimens (4.3%) the denticle row was divided into four sub-rows by three enlarged denticles; and in one specimen (2.2%), the denticle row was divided into six sub-rows by five enlarged denticles. Forty-two (91.3%) of the specimens possessed six inner accessory denticles positioned medially alongside the primary denticle row of the fixed finger, whereas three specimens (6.5%) possessed five inner accessory denticles and one specimen (2.2%) possessed four.

In 42 of the specimens (91.3%), the movable finger bore six sub-rows: an apical sub-row of one denticle followed by five longer sub-rows (Fig. 6). In three specimens (6.5%), the apical sub-row was missing, leaving only the five main sub-rows, and in one specimen (2.2%) there were only four sub-rows. The number of inner accessory denticles of the movable finger varied as follows: 41 specimens (89.1%) had seven, two (4.3%) had six, one (2.2%) had five, one (2.2%) had eight, and one (2.2%) had 10. The specimen with eight inner accessory denticles had the extra one immediately next to the usual basalmost; the specimen with 10 had two extra denticles near the fingertip and the third at the basalmost position.

DISCUSSION

Vaejovis bilineatus is now known to exhibit a wide geographical distribution that includes at least six states in northern and central Mexico: Aguascalientes, Coahuila, Guanajuato, Nuevo León, San Luis Potosí, and Tamaulipas (Fig. 21). The record for "Gonzalez, Mexico; H. F. Wickham" might refer to a small town named Villa González Ortega in Zacatecas, approximately 100 km northeast of San Luis Potosí, where another specimen was collected by Wickham. Even if this is not the case, the presence of *V. bilineatus* would seem extremely likely in Zacatecas, as well as in extreme northeastern Jalisco.

Vaejovis bilineatus is a variable species in terms of color pattern and setal counts. In regard to the latter, it should be emphasized that although setal counts exhibit such great intraspecific variation that their taxonomic value is



Figure 21.—Map of northern and central Mexico depicting the distribution of *Vaejovis bilineatus*.

limited in this case, they are often more consistent in other groups of vaejovids. Most species of *Serradigitus* and the *Vaejovis mexicanus* and *nitidulus* groups, for example, have very consistent setation with only minor variation. Haradon's reliance on pedipalpal setal characteristics to delimit species and species groups in *Paruroctonus* indicates that they are relatively stable in that group as well.

Although variation in pedipalp chela dentition is usually minor, it is important to consider and quantify. It is recommended that, because atypical counts occasionally occur, the investigator check the dentitions of both the left and right chela fingers and examine as many specimens as possible. Variation in movable finger dentition in *Vaejovis spinigerus* (Wood) led Williams (1980) to misidentify specimens of this species from Isla Tiburon, Sonora as *V. gravicaudus* Williams (Sissom 1992). It should also be pointed out that, in some vaejovids, variation in chela dentition may be even less than seen in *V. bilineatus* or nonexistent—this was the case in previous studies on the *Vaejovis nitidulus* group (Sissom & Francke 1985; Sissom 1991).

The new information on color patterns in *V. bilineatus* presents a problem for those using older keys and descriptions to separate this taxon from *V. punctatus punctatus* Karsch. For example, in Hoffmann's (1931) key, the couplet separating the two forms is based entirely on whether specimens have two dorsal stripes or four. Studies on *V. punctatus* are in progress, and this species is also proving to be quite variable, especially in body size, coloration, and setation. Nevertheless, it is possible to distinguish *V. bilineatus* from *V. punctatus punctatus* as follows: in *V. punctatus punctatus*, (1) the internal face of pedipalp patella is flattened with a weak basal tubercle (not convex); (2) the dorsointernal and dorsoexternal carinae of the pedipalp patella are moderate and distinctly crenulated throughout (not weak and smooth to granular); (3) the pectinal tooth counts are usually higher, with male modal counts 18 and female modal counts 16; and (4) body size is distinctly greater with adult males approximately 30–40 mm long and females 40–50 mm. Additional differences will undoubtedly be found as the *V. punctatus* "complex" is revised.

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